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Promoting Sustainable Mining Communities through Integrating the Circular Economy in Construction and Demolition Waste Management: A Case of Unki Mine, Shurugwi, Zimbabwe

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Abstract

The concept of sustainable communities is threatened by various factors, including increased construction and demolition (C&D) waste from the mining sector. Construction and demolition waste from mines contributes to socio-economic and environmental problems. This accentuates the need to shift to a circular economy approach that minimises C&D waste generation and disposal. This study focused on integrating the circular economy into the management of C&D waste from Unki Mine to create sustainable mining communities. A mixed-methods research design was employed to integrate qualitative and quantitative methods. The semi-structured household survey included 42 respondents. A total of 7 key informants were interviewed, and 1 focus group discussion was held with 9 participants. Data collection employed semi-structured questionnaires, interviews, focus group discussions, and field observations. Findings show that C&D waste, including concrete, metal, rocks, plastics, timber, bricks, soil, and tiles, was generated by Unki Mine operations. A large proportion of the waste was composed of metals (27.87%), soil, sand, and rock (24.59%), and a combination of rubble and concrete (21.31%). Only 8.51% of respondents indicated awareness of Unki Mine's approach to waste segregation. Key circular economy practices included repurposing timber and metal waste and the repurposing of rubble and concrete to build structures, pavements, and for gully reclamation. The mine's plans aim to expedite the implementation of approaches that convert waste into energy. The mine's infrastructure development, policy implementation, waste auditing, and awareness programs that support resource circularity, aimed to create sustainable communities in line with Sustainable Development Goal 11.

Keywords

Sustainability; Circular economy; Sustainable community; Construction and demolition waste; Unki mine host communities

Introduction

The management of different forms of waste is currently an escalating global challenge due to population growth, economic development, technological advancements, construction and demolition activities, and urbanisation, among other factors (Agboola *et al.,* 2025; Jerie *et al.*, 2025b). This trend increases pressure on authorities responsible for solid waste management. Kaza *et al.* (2018) indicated that the world is expected to generate 3.4 billion tons of solid waste by 2050, underscoring the need to address the growing volume of waste. Although quantities of various types of solid waste are growing, C&D waste is sharply increasing, accounting for 20% to 50% of solid waste in developed countries (Vincent *et al.,* 2022). In developing countries, the problem of C&D waste is also significant due to its volumes and associated detrimental impacts. Construction waste refers to non-liquid, non-gaseous materials generated during construction activities, such as building or renovating structures. The mining industry is among the major contributors to high volumes of waste (Osmanova, 2025). Segui *et al.* (2023) and Berge and Von Blottnitz (2022) argue that the mining industry, which is fundamental to economic and societal development, generates substantial construction waste that negatively affects atmospheric, aquatic, and terrestrial ecosystems, particularly in developing regions such a*s* Africa. Construction and demolition waste generated by mines encompasses a wide range of materials, including concrete, wood, bricks, glass, plastic, and metal. In 2017, South Africa's mining sector produced approximately 20.2 megatons of solid construction waste (Berge and Von Blottnitz, 2022). In countries like Zimbabwe, accurate data on the quantity and quality of C&D waste from mines is scarce, as few studies have covered this area. Existing literature often focuses on environmental impact assessment, the types of waste generated, and their environmental effects. Few studies integrate circular-economy principles into mine-generated C&D waste. This study addresses this gap. Although there is a gap in the literature covering C&D waste circularity in the mining industry, information on the contribution of mining to economic development is abundant.

In Zimbabwe, the mining sector accounts for approximately 8% of the country's Gross Domestic Product and is a major source of export revenues and job creation (Manyuchi, Mbohwa and Muzenda*,* 2019). Given its extensive mineral resources, this indicates that, the mining sector is a fundamental pillar of Zimbabwe's national development strategy. The mining industry is crucial for economic growth and employment creation in Zimbabwe (Musevenzo *et al.,* 2024), thereby reducing the burden on attaining the country's Vision 2030. Despite its societal, political, and economic significance, the mining sector faces environmental criticism for disrupting natural ecosystems and human livelihoods. Numerous mines, including those involved in gold, platinum, chrome, and lithium mining, generate solid waste, such as construction and demolition (C&D) waste, which contributes to the emergence of notable environmental health problems (Chihiya, Nhedzi and Mapira*,* 2022; Magidi and Hlungwani, 2023; Mutsvanga, Mapira and Ngaza*,* 2018). The management of C&D waste from mines in Zimbabwe is characterised by a conventional linear approach that frequently leads to contamination of soil, water, and land, as well as rapid depletion of landfill space (Chihiya, Nhedzi and Mapira, 2022; Mutsvanga, Mapira and Ngaza*,* 2018). The management of C&D waste from mines also applies to open dumping, land filling, and burning, approaches that have the potential to cause outbreaks of respiratory and

waterborne diseases. Illegal dumping of C&D waste from mines contaminates land used for agriculture, yet Muwaniki, Wedekind, and McGrath (2024) argued that most communities in Zimbabwe depend on agriculture for their livelihoods.

At Unki mine, C&D waste accounts for a notable share of waste. However, the mine has demonstrated a commitment to environmental responsibility by implementing strategies that minimise environmental problems. Most existing methods for managing C&D waste are geared toward green mining; however, they need to be advanced further to reduce the burden of achieving sustainability. Unki Mine prioritises strategies higher on the waste management hierarchy by the waste management hierarchy, thus supporting circularity. This is essential for achieving sustainable mining communities. The circular economy approach emphasises the application of reduction, recycling, reuse, repair, and recovery principles, which support sustainability (Jerie *et al.*, 2025b; Toponar *et al.,* 2024). Informed by the existing situation, this study focuses on integrating the circular economy to advance sustainable communities by utilising C&D waste. The study focused on construction and demolition waste generated at Unki Mine, its management, potential environmental impacts, and the benefits of integrating a circular economy approach to managing C&D waste. In this study, C&D waste refers to materials generated during the construction, renovation, and demolition of buildings, infrastructure, and other built environment structures, as well as during construction site clearance.

This study contributes by proposing a framework that demonstrates the essential role of C&D waste in sustainable community development, thereby offering valuable insights for policy-making. Therefore, the significance of the research is evident in its ability to contribute to policy-making and pave the way for appropriate management of C&D waste, thereby safeguarding the environment and the people living in mining communities. This enabled mines in Zimbabwe to adopt Sustainable Development Goals (SDGs) aligned strategies to manage C&D waste. Appropriate management of C&D waste facilitates the achievement of the SDGs on good health and well-being (3), clean water and sanitation (6), sustainable cities and communities (11), responsible consumption and production (12), and climate action (13). This lessens the burden on Zimbabwe to attain its Vision 2030 aspirations, particularly those that advocate for good health and well-being, water and sanitation, and sustainable development, to reach the upper-middle-income class by 2030. The research was guided by the following questions: (1) What are the types of construction and demolition waste generated by Unki Mine? (2) What are the strategies used to manage construction and demolition waste from Unki Mine? (3) What are the impacts of prevailing construction and demolition waste management approaches? (4) What are the benefits of integrating circular economy approaches in the management of construction and demolition waste?

Materials and Methods

Description of the Study Area

The research was conducted at the Unki mine, located approximately 60 kilometres from Gweru in Shurugwi, Midlands Province, Zimbabwe (Figure 1). Unki lies within the Chironde Range of the Great Dyke, a 550-kilometre-long geological formation rich in platinum-group metals (PGMs), chromium, nickel, and gold. Occupying an elevated

position on Zimbabwe's Highveld, Unki Mine sits at an altitude of 1,200–1,500 meters above sea level between the Mtebekwa and Mtebekwana Rivers. The Unki mine is located in Agro-ecological Region 3, characterised by annual rainfall ranging from 650 mm to 800 mm, average temperatures between 18–25°C, and distinct wet (November–April) and dry (May–October) seasons (Muringaniza *et al.,* 2025). The vegetation is dominated by dry miombo woodlands, characterised by species such as *Brachystegia spiciformis and Julbernardia globiflora.* Communities around the Unki mine consist of resettlement schemes, communal lands, and agricultural cooperatives on former commercial farms to the south and west (Masuku, 2022). Unki Mine employs a workforce of which approximately 25% are local residents, to carry out various activities (Masuku, 2022), including construction activities that generate C&D waste, requiring adequate attention to safeguard host communities.

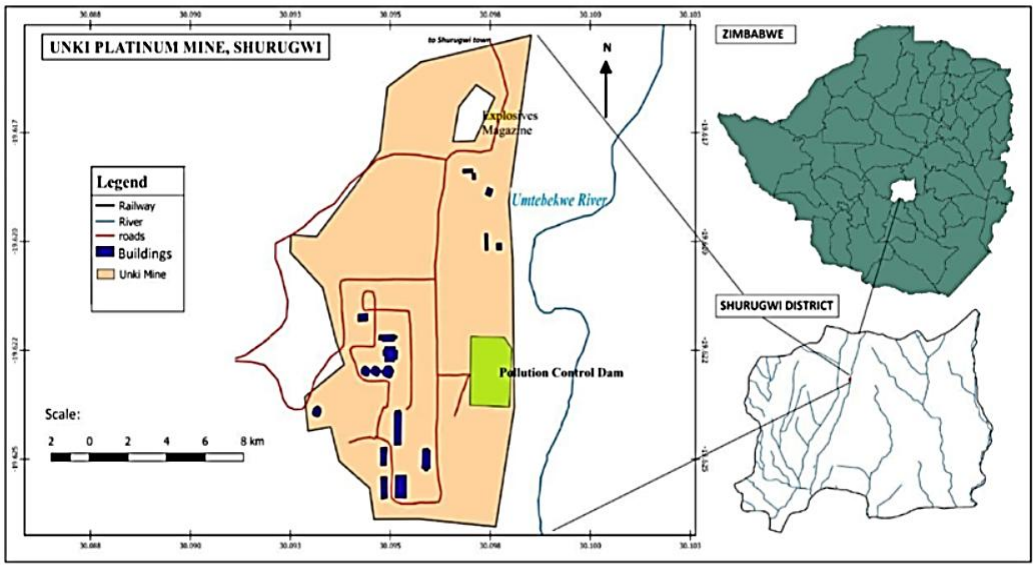

Figure 1: Unki mine location in Zimbabwe [*Source:* Chihiya, Nhedzi and Mapira (2022)]

Research Design

This study employed a mixed-method research design, which facilitated the triangulation of qualitative and quantitative methods in data collection, analysis, and presentation. Semi-structured questionnaires, interview guides, focus group discussion guides, and observation checklists were utilised to collect data over 5 working days. Analytical approaches applied in the study encompass quantitative methods using the Statistical Package for the Social Sciences to analyse quantitative data and qualitative methods using content analysis to analyse qualitative data. Percentages were computed from tables, pie charts, and graphs.

Target Population and Sample Size Determination

The study targeted household heads in Unki Mine's host communities as respondents for a semi-structured questionnaire. As a result, the study targeted 42 households in the host

community during the questionnaire survey. The study followed Glenn's (1992) view, which holds that, in research, if the target population is below 200, the entire population is used as the sample. Consequently, a census sampling approach was employed. To ensure all households were included, a list was created and used to verify their participation. Targeted key informants with extensive knowledge of the topic were purposively selected to participate as interviewees (Table 1).

During observations, the researcher focused on the generation and disposal of C&D waste and its potential environmental impacts. Nine members of the Community Engagement Forum, consisting of 4 males and 5 females, were specifically targeted and selected to participate in the focus group discussion, as they are knowledgeable about Unki mine operations and represent the community. Members of the Community Engagement Forum were selected because they served as intermediaries between the mine and local communities and usually represented those communities. In terms of age, the focus group discussion (FGD) participants were approximately 30 years of age or older. The FGD lasted 1 hour, and the issues raised by the respondents were recorded in a notebook after obtaining participants' consent. To avoid dominance by other participants, the FGD was moderated by inviting quiet participants to express their views. Moreover, clear rules were established that allow everyone to contribute, reducing the participation of the same individuals. Data collected through FGD were analysed using content analysis, as the data were qualitative in nature.

Table 1: Key informants and reasons for choosing them

Key informant	*Number of Informants*	*Reason for choosing the informant*
Unki Mine Community Engagement Officials	2	Their knowledge of community perspectives, concerns, and experiences will ensure that the voices and needs of the host communities are considered.
Environmental Management Official	1	Their knowledge of local environmental regulations, policies, and concerns will inform the development of a circular-economy framework.
Tongogara Rural District Council Official	1	Their understanding of local development priorities, challenges, and opportunities will help integrate the circular economy framework.
District Development Coordinator's Office Official	1	Their understanding of local development priorities, challenges, and opportunities will help integrate the circular economy framework.
Local leadership within mine's host community	2	They are the voices of the community people.

Data Collection, Analysis, and Presentation Methods

To address the research demands, data were collected using questionnaires with both open-ended and closed-ended questions (Appendix 1), semi-structured interview guides (Appendix 2, 3, 4, 5, and 6), focus group discussions (Appendix 7), and observation

checklists (Appendix 8). These data collection methods were utilised to gather data on the types of C&D waste, the C&D waste management strategies applied, and the environmental and socio-economic impacts of C&D waste from the Unki mine, as well as opportunities to build community resilience by integrating the circular economy into C&D waste management from the Unki mine. To complement the collected data and enhance the validity and reliability of the research, existing literature from secondary sources, including Unki Mine's Annual Reports, Social Performance Reports, Community Engagement Forum Reports, and External Context Review reports, was utilised. The collected quantitative data were analysed using the Statistical Package for the Social Sciences. Descriptive statistics, such as mean, mode, and frequency, were used to report response rates, primarily for data collected via questionnaires. Quantitative data were presented in the form of tables, charts, and graphs. Qualitative data were subjected to content analysis and presented through expressive, persuasive narratives, incorporating both direct and indirect quotations. Quantitative and qualitative data were analysed separately, and the results were triangulated during the interpretation phase to determine where the data converged, complemented each other, or contradicted.

Results and Discussion

Types of Construction and Demolition Waste Materials Generated by the Unki Mine

Data from questionnaires, observations, interviews, and focus groups identified the following types of C&D waste, and focus group discussions concur. Broad categories of C&D waste generated include metal, rubble and concrete, timber, glass, polythene, organic waste, soil, sand, and rock waste (Table 2). Table 2 illustrates the broad categories of generated C&D waste, along with examples of components within each category.

Table 2: Broad categories of construction and demolition waste and their components

Broad categories of generated waste	*Examples of components of each broad category*
Metal Waste	Structural steel, reinforcement bars, copper wiring, decommissioned machinery, aluminium fixtures, and extensive piping systems
Polythene Waste	Drums, buckets, plastic pipes and liners, plastic packaging materials.
Rubble and Concrete	Asphalt rubbles, masonry rubbles, broken bricks, and concrete.
Timber Waste	Discarded roofing materials, wooden crates, and utility poles.
Organic waste	Food scraps and green waste
Soil, sand, and rocks	Soil, sand, and rocks are considered waste after being removed from open construction sites.
Glass waste	Broken window panes, discarded lighting fixtures such as fluorescent tubes and bulbs, and shattered glass components.

In terms of the contribution of each type of waste to the C&D waste stream, figure 2 and table 3 present these contributions as percentages. Percentages in table 3 and figure 4

were based on an estimate of approximately 25,300 kilograms of C&D waste generated during the data-collection period. Metal materials, such as structural steel, reinforcement bars, copper wiring, decommissioned machinery, piping system materials, and aluminium fixtures, constitute a large proportion (27.87%) of C&D waste generated by the Unki mine. An interview with the Unki Mine Community Engagement Officials and Environmental Management Official also indicated that the Unki mine is among the industries that require extensive use of metal for fencing and the construction of ball mills, incinerators, and other critical structures for mining operations. These results align with Šajn, Ristović, and Čeplak (2022), who found that the mining sector is among the significant generators of C&D waste in the form of metals. The total amount of soil, sand, and rock in the C&D waste stream was 24.59% removed to clear construction sites (Table 3). Rubble and concrete account for 21.31% (Table 3; Figure 2) of the C&D waste generated at the Unki mine, indicating that they were also produced in significant quantities. The mine generates rubble and concrete waste during construction and renovation projects within the mine and surrounding communities. A view supported by Shengo (2021) that mining industries generate rubble and concrete waste during extraction, infrastructure development, and maintenance of roads, processing facilities, and tailing dams. Observations and results from the focus group discussion indicate that C&D waste, in the form of timber, organic waste, and glass, was generated in low volumes. This was also evident in the proportions of these types of waste relative to the total C&D waste (Table 3; Figure 1). Glass waste from Unki Mine accounted for a low proportion of 3.28%, a figure almost similar to that reported by Yeheyis *et al*. (2013) of 3.5%. Moreover, rubble and concrete from the mine accounted for 21.31%, a figure illustrated by Yeheyis *et al*. (2013), who studied this type of waste at a notable proportion of 23.9%.

Table 3: Contribution (%) to the total construction and demolition waste from Unki mine

Type of C&D waste	*Contribution (%) to total C&D waste*
Metal	27.87
Rubble and concrete	21.31
Timber products	8.2
Polyethylene	9.84
Glass	3.28
Organic waste	4.92
Soil, sand, and rock	24.59

Management of Construction and Demolition Waste Generated from the Unki Mine

Segregation of C&D Waste

Management of C&D waste from the Unki mine was characterised by segregation at source, incineration, donation, and open dumping (Table 4; Figure 3). At the Unki mine, segregation of C&D waste was reported by 8.51% of respondents. This was in line with Unki Mine Community Engagement Official's response during the interview that:

> *"Segregation works well for waste takers and supports recycling efforts at Unki mine, but needs to be enhanced through awareness campaigns which raise knowledge among employees".*

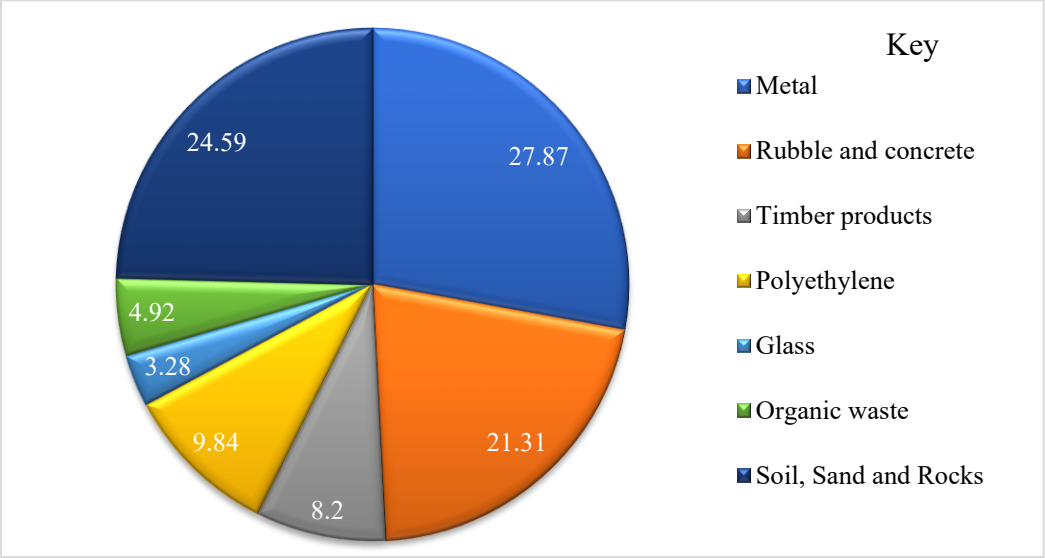

Figure 2: Contribution (%) to the total construction and demolition waste from Unki mine

Field observations indicated that metal and plastic scraps were stored in separate bins, each labelled or distinguished by a different colour. This indicates the mine's emphasis on segregation to support circular practices; however, behaviour change programs to eradicate indiscriminate waste storage must be implemented regularly. This is because it is difficult to achieve proper solid waste separation due to people's limited attention to the process (Shabani, Mutekwa and Shabani, 2024). Although Unki mine conducts training and awareness programs to raise workers' awareness and reduce obstacles to achieving sustainable mining communities, it must also share its circularity ideas with other mines in the area. During interviews Unki Mine Community Engagement Officials indicated that segregation of C&D waste is highly prioritised, as indiscriminate management hampers efforts to apply the circular economy, which is the mine's target.

Incineration

Incineration was also among the methods used to manage C&D waste, encompassing wood and plastic materials, as indicated by 36.17% of questionnaire respondents (Table 4; Figure 3). Interviews with the Unki Mine Community Engagement Officials demonstrated that the mine adopted incineration because it has the potential to reduce waste volumes by turning large volumes into ash. The incineration process can reduce the mass of solid waste by 80-90% (Barbhuiya *et al.,* 2021). Reducing the volume of disposed waste extends the lifespan of disposal sites and prevents the destruction of vegetation to create new sites; however, incineration can emit greenhouse gases. Unki mine's incinerator serves its purpose effectively and is characterised by a well-structured combustion chamber that facilitates complete combustion, limiting the emission of toxic gases into the atmosphere. This is in line with Chapter 20:27 of the Environmental Management Agency (EMA) Act (Atmospheric Pollution Control) regulations, 2009, which state that the operation of an incinerator should not result in excess emissions into the atmosphere (Government of Zimbabwe (GoZ), 2009). This is essential for

minimising respiratory problems and climate change. According to the EMA Act, the chimney of every polluting appliance should be 50 meters, and the mine adhered to this by constructing the incinerator's chimney to the required standard. Moreover, the mine's plan to equip its incinerator with systems to facilitate energy recovery is significant in the context of the circular economy.

Table 4: Strategies used to manage construction and demolition waste generated by Unki mine.

Management strategy	*Percentage of respondents*
Segregation	8.51
Incineration	36.17
Donation	27.66
Open dumping	27.66

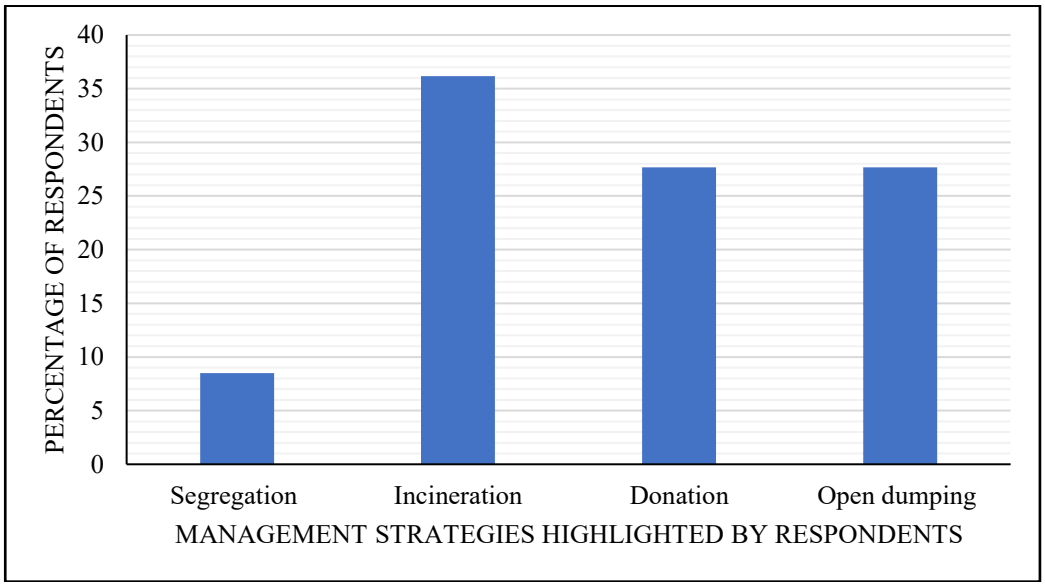

Figure 3: Construction and demolition waste management strategies highlighted by respondents.

Dumping

The utilisation of open dumping in the management of different types of C&D waste in Southern African countries is high, and Zimbabwe is no exception (Jerie, Shabani and Shabani, 2024). Open dumping of C&D waste, such as rubble, concrete, and rocks generated by the Unki mine, was identified as a common practice by respondents (27.66%) (Table 4; Figure 3). C&D waste generated at the Unki mine was disposed of in designated salvage yards, thereby reducing its accessibility to people and animals. Placing C&D waste in protected areas reduces scavenging, thereby protecting people from injuries associated with scavenging. Discarding solid waste in secure locations is essential to safeguard human well-being, but it also contributes to land pollution and represents a missed opportunity for applying circularity principles (Jerie *et al.*, 2025a).

Donation of Reusable Materials to Communities

A total of 27.66% of questionnaire respondents agreed that Unki mine donated some of the construction materials to communities for reuse (Table 4; Figure 3). Data from focus group discussions and interviews with the Unki Mine Community Engagement Officials indicated that, instead of disposing of everything generated during construction, the mine donated some of the used materials to the community to support development. This initiative involves redistributing items such as timber offcuts, used furniture, containers, metal materials, and outdated equipment to neighboring communities as expressed by District Development Coordinator's Office Official and Local leadership within mine's host community. The programme exemplifies corporate social responsibility by simultaneously reducing landfill-bound waste and providing material resources to under-resourced populations. Donating used materials to communities extends their lifespan, thereby reducing pressure on the environment, particularly at disposal sites. The initiative presents significant merits, but to maintain the mine's good reputation, it can include follow-up strategies to monitor use and ensure future disposal. This goes in line with studies which demonstrated that donation of materials to other people for reuse may extend material life but require monitoring (Wu and Cerceo, 2021).

Policies Governing Construction and Demolition Waste Management in Zimbabwe

In Zimbabwe, waste is governed by the Environmental Management Act [Chapter 20:27]. The Environmental Management Agency oversees waste management, including C&D waste, under the Environmental Management Act. Unki Mine adheres to EMA guidelines by implementing waste management activities to minimise C&D waste, including onsite storage, segregation, transportation to the dump site, and proper disposal. Everyone who produces waste, including C&D waste, should be responsible for managing it properly to protect the environment and human health, according to section 73 of the EMA Act. The EMA Act [Chapter 20:27] lists all projects that require Environmental and Social Impact Assessment (ESIA), including projects that produce C&D waste. The Environmental and Social Impact Assessment states that landfills should be sited in accordance with EMA Act standards to protect communities from hazards associated with improper waste disposal. Section 95 of the EMA Act protects communities by prohibiting the dumping of solid waste, such as C&D waste, close to residential areas (Parliament of Zimbabwe, 2002).

To protect the community from hazards associated with C&D waste, Unki Mine conducts an ESIA before commencing projects that may generate C&D waste. According to Nhavira (2019), host communities benefit from Unki Mine's corporate social responsibility initiatives. Additionally, in Zimbabwe, section 47 of the Mines and Minerals Act [Chapter 21:05] requires a holder of a registered mine to peg an area for waste dumping to protect residents and the environment from hazards arising from waste. Unki Mine complies with this act by pegging its waste dumps in accordance with section 47, subsection 2. In Zimbabwe, the management of hazardous substances is regulated by the Hazardous Substances and Articles Act [Chapter 15:17] (EMA, 2007). However, it does not specifically mention construction and demolition waste, but it provides guidelines for managing the hazards associated with such waste. Some waste generated during construction and demolition projects, such as asbestos, is hazardous

because of its harmful environmental and human health effects. Unki Mine disposes of hazardous C&D waste in accordance with the Act's requirements, including protecting the environment and human health.

Potential Impacts of Applied Construction and Demolition Waste Management Approaches

Results from the study indicate that the approaches used to manage C&D waste can affect both environmental and socio-economic aspects (Figure 4). Perceptions of questionnaire respondents (40%) (Table 5; Figure 4) and key informants namely Environmental Management Official and Tongogara Rural District Council Official acknowledged that failure to integrate the circular economy principle fully can result in environmental pollution. Findings indicated that the mine must fully adopt the circular economy concept to mitigate the detrimental impacts of C&D waste on soil, water, and air. Unki mine must quickly implement its plans to embed circular principles in its handling of piles of discarded C&D waste before the dumping areas are exhausted. This is an essential action to prevent the need to open new dumpsites, a situation that leads to vegetation destruction and ecosystem disruption. Besides causing pollution, areas with large tracts of land occupied by idle waste heaps are usually devoid of vegetation and other land uses (Alsheyab, 2022; Viswalekshmi *et al.,* 2024). Furthermore, a delay in applying circularity in managing disposed waste may result in water pollution, as debris, sediments, and other hazardous substances from disposed C&D waste can be transported and discharged into nearby water sources. A scenario that can potentially hinder the availability of water for agriculture, bathing, and washing for local people, thereby hindering the attainment of sustainable goals such as access to clean water and sanitation (6).

During C&D waste management, dust often rises and can negatively affect residents by exacerbating persistent coughing, sneezing, and nasal congestion (Sharma, Garg and Li, 2024). To address concerns about dust generated during C&D waste management, Unki mine implemented water-suppression measures. It maintained roads used by trucks for transporting C&D waste. Suppression of dust paves the way to achieving the global goal of good health and well-being (3), which, in turn, translates into the attainment of Zimbabwe Vision 2030 targets in Unki's host communities. Although these approaches are vital, enhancing the utilisation of vegetation is crucial, as it is a long-term approach. Dust from C&D waste contains silica dust, wood dust, asbestos fibres, cement dust, and heavy metals (Jerie, Shabani and Shabani, 2024). After recognising this, Unki mine prioritises the safety of involved workers by providing them with appropriate personal protective equipment (PPE) and clothing, as well as information on PPE donning and doffing. This demonstrates Unki Mine's support for the SDGs and Zimbabwe Vision 2030's goals, which aim to promote decent work for all.

Table 5: Potential impacts of construction and demolition waste

Potential impacts of C&D waste	*Percentage of respondents*
Environmental	40
Economic	25
Social	35

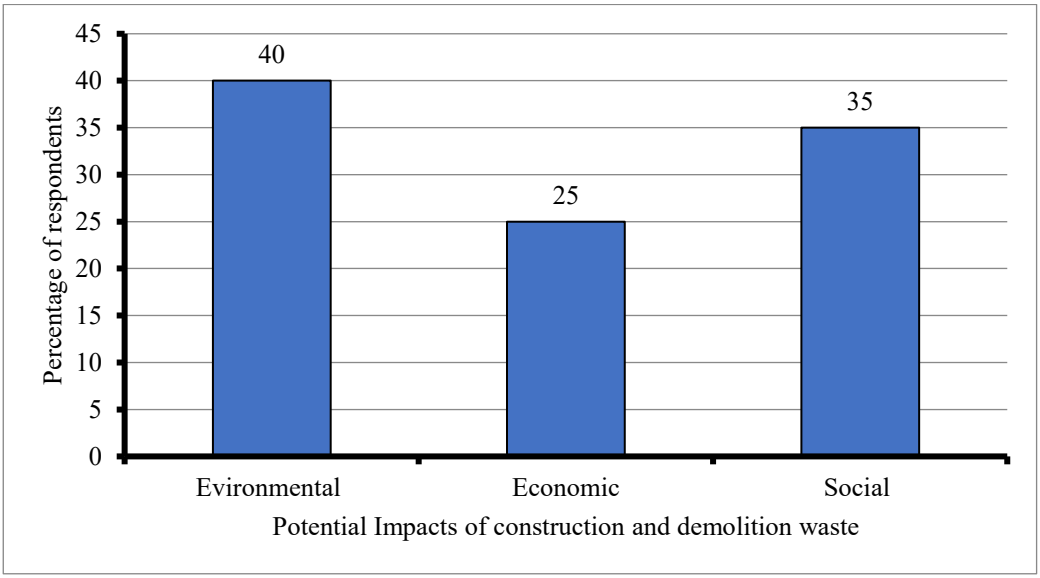

Figure 4: Potential impacts of construction and demolition waste

Inappropriately disposed of C&D waste and the creation of disposal sites disrupt established land use patterns (Padhiary and Kumar, 2024). Interviews highlighted that grazing, farming, and cultural sites can be encroached upon if C&D waste is not properly addressed; however, the Unki mine is currently doing its best to avoid such scenarios. This is supported by the views of Unki Mine Community Engagement Officials and Tongogara Rural District Council Official, who are aware that converting grazing and arable land into dumping sites not only affects animal rearing in the area but also exposes people to land conflicts and food insecurity. This was also reflected in the perceptions of questionnaire respondents (35%), who highlighted potential social impacts of C&D waste (Table 5; Figure 4). This signifies that the plan to scale up the adoption of the circular economy approach is not only centred on environmental protection but also on the goal of zero hunger. This aligns with studies indicating that the circular economy approach reduces the burden of achieving other Sustainable Development Goals (SDGs), exemplified by SDG 1 (No Poverty) and 2 (Zero Hunger), among others (Vaverková, 2025; Weißert, Henzler and Kassahun, 2025). The District Development Coordinator's Office Official noted that some people in Unki mine host communities also generate income to support their families and start businesses through farming and fishing activities. Therefore, the inappropriate management of C&D waste may hinder economic growth in the area, a situation also asserted by 25% of questionnaire respondents (Table 5; Figure 4). This, among other reasons, explains why the Unki mine is currently adopting and aiming to advance the use of management approaches that avert pollution of water sources, which serve as sources of fish and land, sustaining agriculture. Additionally, Unki mine authorities indicated that they have realised that disposal of large volumes of C&D waste is a waste of resources. Hence, to reduce the purchase and extraction of new and raw materials, they have begun integrating circular economy principles into C&D waste management, although adoption is still in its embryonic stage.

Integrating Circular Economy Principles in Managing Construction and Demolition Waste: Possible Approaches and Significance

The Environmental Management Official highlighted that advancing the implementation of circular economy (CE) principles in managing C&D waste is essential to address socio-economic and environmental problems. Environmental Management Official clearly articulated that implementing strategies such as reducing, reusing, recycling, and repurposing at a high rate can improve infrastructure while fostering entrepreneurship in local communities. Environmental Management Official, Tongogara Rural District Council Official and focus group discussion results indicate that, to implement approaches to recover valuable materials from C&D waste, Unki mine is advocating a participatory approach. This aligns with community suggestions who were questionnaire respondents suggested utilising concrete rubble to manufacture paving blocks for rural footpaths and road surfaces, and to reuse blocks to build toilets. Reusing concrete rubble for other purposes minimises pressure on disposal sites and facilitates infrastructural development at minimal cost in surrounding communities (Caro *et al.,* 2024; Nie, Dahanayake and Sumanarathna*,* 2024). In the context of the Unki mine, the reuse of concrete rubble is crucial for reducing environmental impacts, as it accounts for a significant volume of C&D waste, as identified through observations and questionnaire responses (27.87%).

Informal welders and artisans, who were among the members of the focus group discussion, proposed transforming scrap metal into school desks, fencing materials, benches, and artistic installations for public spaces. At Unki mine, it was observed that metal drums have been converted into waste bins and steel sheets have been reused for school roofing; however, further approaches to strengthen these efforts are required. Strategies to increase awareness among relevant parties and encourage segregation of solid waste are crucial to reducing the burden of extracting metal scrap for reuse. After donating C&D waste, such as metal scrap, to the community, mines must conduct follow-up to provide the resources required by small-scale metal workshops, enabling them to turn metal waste into useful products. Therefore, Unki mine must strengthen its C&D waste management policy and share with other mines the idea of supporting community projects, particularly those involving metal fabrication. This is ascribed to the fact that metal fabrication contributes significantly to employment and the country's economy (Jerie *et al.*, 2025a). Therefore, it can create employment opportunities for local people, particularly young people, while contributing to economic development, thereby paving the way for youth empowerment in Zimbabwe. Unki mine, in collaboration with host communities, is investing in projects that support the reutilisation of timber waste to construct habitats for domestic animals, as well as making chairs and tables for schools and domestic use. Converting timber waste into useful products not only reduces environmental pollution and the destruction of fauna but also reduces the need to purchase new products and provides income opportunities for carpentry groups and cooperatives (Adhikari and Ozarska, 2018).

Verdicts from focus group discussions indicate that people in local communities viewed plastic waste as a valuable input for plastic-based products. They argued that plastic materials can be utilised as shopping and storage bags, as well as for producing plastic bricks and roof tiles. Women and youths who participated as questionnaire respondents

and focus group members proposed forming cooperatives to collect, sort, clean, and reuse or process plastics into new products. However, they mentioned that although Unki mine is supporting them, the shortage of resources essential to convert plastic waste materials into new products remains a problem. Additionally, to advance its community support activities, Unki mine may consider constructing a plant that converts plastic waste into fuel through pyrolysis. In terms of applying methods that enable energy recovery, Unki mine can construct an incinerator to facilitate energy recovery from waste. This aligns with SDG goal 7, target 7.c, which calls for expanding and upgrading energy infrastructure, as the generated energy will be added to the Unki mine's power grid. Plastic containers produced as waste during construction activities were recovered from dumping areas and reused as flower or tree seedling pots. The reutilisation of items such as plastic materials extends the lifespan of dumpsites, while also reducing land pollution (Shamsuddin *et al*., 2025; Zavadskykh *et al*., 2025), thereby suppressing human ailments related to pollution.

Environmental Management Official suggests using rubbles, rocks and soil in land leveling, road construction and gully reclamation in host communities, strategies which already exist in managing C&D waste from Unki Mine. Glass waste, though less common, also presented significant opportunities for reuse and recycling since respondents proposed crushing glass into fine aggregates for decorative concrete finishes, reflective road beads or as additives for tile production. To achieve this, respondents recommended establishing small-scale glass crushing and moulding units through collaboration among technical colleges, Unki mine members, and community members to foster skills sharing and development. Existing information suggests that Unki mine can further develop its existing circular approaches, as outlined in its plans and guidelines in figure 5. Key possible strategies to enhance the degree of circularity adoption and reduce socio-economic and environmental problems associated with C&D waste include infrastructure development, stakeholder collaboration, funding to promote project formulation and innovation, and C&D waste auditing and awareness programs. Integrating the proposed circular construction and demolition waste management approach with other strategies supports sustainability. Adopting circular economy principles in managing solid construction waste from the Unki mine presents numerous significant benefits, as shown in table 3. The circular economy integration framework illustrated by Figure 5 includes aspects that are also upheld by the MacArthur Foundation’s 3R model, which supports reduce, reuse, and recycle. The model supports minimisation of C&D waste at source, reusing of components for new projects, and recycling of materials such as concrete into aggregates essential for the construction of new structures.

Unki Mine has effectively implemented several crucial elements of its circular economy model, and this has brought various benefits that have been realised by the mine (Table 3). Cost savings from reusing resources and avoiding new purchases, as well as regulatory compliance and environmental standards, are examples of tangible results. Moreover, by significantly reducing pollutants and landfill waste, the mine has also improved environmental protection. Efforts to use resources more efficiently have reduced the need for new raw materials, thereby limiting disturbance of the natural ecosystem. These implemented initiatives contribute to the broader, projected aims of economic growth, reduced carbon footprint, and improved public health through

ongoing responsible management of C&D waste. Although a specific number of jobs created by the circular economy approach is not provided, the application of circular economy principles in the management of C&D waste supports people's livelihoods while reducing conflicts between the mine and local communities. Besides the contribution of the circular economy to safeguarding the environment and public health, mining operations also realise other benefits, including cost savings.

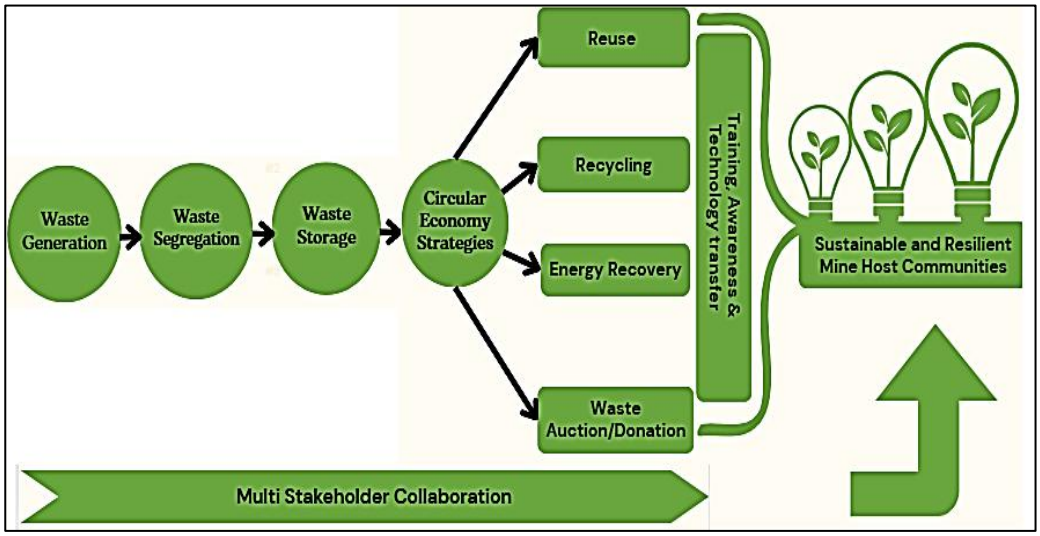

Figure 5: General guideline of the mine's circular construction and demolition of waste management approach

Table 3: Summary of the potential significance of the circular economy approach realised by Unki mine

Significance	*Description*
Environmental protection	Reduces landfill waste, minimises soil, water, and air pollution, and reduces biodiversity loss.
Efficient use of resources	Maximises the use of existing materials, thus lowering the need for new raw materials.
Cost savings	Reduce the cost of purifying contaminated water and of procuring new products. Minimise the cost of creating new disposal sites and monitoring of dumpsites.
Economic growth	Recycling, energy recovery, and processing activities generate income and create employment.
Regulatory compliance	Supports compliance with environmental regulations and waste management policies.
Reduced carbon footprint	Reduction of energy consumption and emissions associated with the extraction, processing, and transportation of new raw materials.
Improved public health	The circular approach contributes to the sustainable management of C&D waste, thereby reducing health issues associated with improper waste management and conflicts between mine and host communities.

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Conclusion and Recommendations

Construction and demolition waste from mines presents a significant environmental challenge impacting different provinces in Zimbabwe. Unki mine is among the mines that produce large volumes of C&D waste. C&D waste generated broadly includes metal (27.87%), rubble and concrete (21.31%), timber products (8.2%), polyethene (9.84%), glass (3.28%), organic waste (4.92%), and soil, sand, and rock (24.59%). Generated C&D waste has the potential to cause environmental health problems, as highlighted by respondents' perceptions, including those in questionnaires who indicated environmental (40%), economic (25%), and social (35%). To address environmental health problems, Unki Mine manages C&D waste using SDG-aligned approaches, particularly those supported by circular-economy principles such as segregation, reuse, and donation of materials for reuse and repurposing. The application of segregation, reuse, and donation of materials is equally important and complements each other, as each contributes uniquely to the attainment of the circular economy approach.

Unki mine's adherence to circular economy principles is evidenced by interventions such as donating reusable materials to the community, investing in projects that use timber and metal waste to produce new products, and reusing rubble and concrete to construct structures, pavements, and gully reclamations. These initiatives present Unki mine's plans to create thriving mining host communities to achieve SDGs 3, 6, 11, 12, and 13, scenarios that facilitate the attainment of Zimbabwe's Vision 2030 of becoming an upper-middle-income country. While the study contributes to sustainability discourse, its single-case design limits generalizability to other mining sites. This is attributed to the fact that the characteristics of Unki Mine may not reflect those of other mines, as mine policies and infrastructure vary significantly. Moreover, the study was conducted in a short period; hence, it cannot clearly reflect the effectiveness of integrated circular economy strategies. Addressing the limitations of the research requires future studies to move beyond single-case studies and conduct long-term studies whose results provide insights into transformative waste management. Future studies should incorporate material-flow analysis and life-cycle assessment.

Recommendations

i. Unki Mine may consider continuation in reviewing its environmental policies with the use of a multi-stakeholder approach to ensure no host communities and stakeholders are left behind.
ii. Unki Mine can partner with local enterprises, civil society organisations, and other mining companies to implement approaches that support the sustainable management of C&D waste.
iii. In collaboration with the Environmental Management Agency, Unki Mine may enhance the implementation of strategies to enhance the participation of host communities in waste management initiatives and programs, which are in line with circular economy concepts.
iv. Unki Mine could work with municipal authorities, environmental agencies, and community leaders to establish key performance indicators used to measure the success of the integrated circular economy approach. Key performance indicators

can be exemplified by the quantity of C&D they want to manage through the circular economy approach by 2027.

v. Unki Mine can establish transparent tracking mechanisms, reports, and polices for waste generation, management, and recycling rates to check progress towards achieving sustainability.

These recommendations collectively advance the attainment of SDGs by creating a systematic shift towards a circular economy in the management of C&D waste in the mining sector. Reducing C&D waste-induced environmental and health problems through policy alignment and partnerships directly contributes to good health and well-being (SDG 3) and clean water and sanitation (SDG 6). Moreover, by engaging host communities and environmental management agencies, the recommendations foster the inclusion of various stakeholders, as also upheld by Goal 11 of Sustainable Cities and Communities. Encouraging the adoption of circular approaches, which limit volumes of disposed waste, means emissions from disposal sites are reduced, a scenario that supports SDG 13 (Climate Action) through lowered carbon emissions.

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Appendices

Appendix 1: Questionnaire for households

Section A: personal details (please tick where appropriate)

1. Gender.

Female		Male	

2. Age.

18-30yrs		31-40yrs		41-50yrs		50+yrs	

3. Level of education

None		Primary		Secondary		Tertiary	

4. Duration of stay in the community.

0-5yrs		6-10yrs		11-15yrs		16-20yrs	

Section B: Awareness and Knowledge

5. Are you aware of the concept of a circular economy?
☐ Yes ☐ No ☐ Somewhat
6. How did you learn about circular economy practices using solid waste?
☐ Community meetings ☐ Training workshops ☐ Social media ☐ NGOs ☐ other (specify): _____
8. Do you understand how construction and mine waste can be reused or recycled?
☐ Yes ☐ No ☐ Somewhat
9. Do you think the community has enough knowledge or information to implement circular economy strategies effectively?
☐ Yes ☐ No ☐ Not Sure
- If No, what information or training is missing? _____

Section C: Current Practices

10. What types of solid construction or mine waste are reused in your community? (Check all that apply)
☐ Bricks ☐ Rubble ☐ Slag ☐ Sand ☐ Concrete ☐ other (specify): _____
11. What are these wastes used for? (e.g., road construction, housing, paving, etc.)
_____
12. Who is mainly involved in reusing the waste?
☐ Individuals ☐ Community groups' ☐ Local government ☐ Private companies ☐ NGOs
13. Are there designated collection points for these materials?
☐ Yes ☐ No
14. Is there a formal process for sorting and preparing the waste for reuse?
☐ Yes ☐ No ☐ not sure

Section D: Perceived Benefits and Challenges

15. What benefits have you observed from reusing mine/construction waste? (Check all that apply)
☐ Job creation ☐Clean environment ☐ Affordable materials ☐ Skills development ☐Other: _____
16. What challenges or limitations have you experienced? (Check all that apply)
☐ Lack of tools ☐ Lack of market ☐ Health/safety concerns ☐ Poor waste quality ☐ Lack of training ☐ Regulations ☐ other: _____
17. Are there health or environmental concerns related to the current waste reuse practices?
☐ Yes ☐ No
- If Yes, please explain: _____

Appendix 2: Interview guide for Local leadership within mine's host community

Introduction

- Welcome participants and explain the purpose of the discussion.
- Emphasize confidentiality, voluntary participation, and respect for all voices.
- Briefly introduce the concept of a circular economy (e.g., "reusing waste to create value").

Key Questions

1. How is mine construction waste currently being managed within Unki Mine's host communities?
2. What are the benefits brought to you by the construction waste that is produced by Unki Mine?
3. What are the biggest environmental or health challenges your community faces due to construction waste from the mine?
4. How does Unki Mine engage with traditional leaders on construction waste management issues? Are these efforts effective?
5. As a leader, how do you involve the community in decisions about waste management and mining activities?
6. What challenges currently hinder effective partnerships between the mine and stakeholders in addressing construction mine waste issues?
7. Are there traditional practices, cultural beliefs, or local innovations locally that could help repurpose construction mine waste that benefit the environment, people, and the climate?
8. What is your role in ensuring host communities actively participate in and benefit from circular economy initiatives?
9. Have waste-related disputes arisen between the mine and the community? How were they resolved?

Appendix 3: Interview Guide for Unki Mine Community Engagement Officials

Introduction

- Welcome participants and explain the purpose of the discussion.
- Emphasize confidentiality, voluntary participation, and respect for all voices.

Key Questions

1. What are the types of construction mine waste materials produced by Unki Mine?
2. How do you currently engage with host communities regarding construction waste management, and what level of awareness exists about circular economy approaches?
3. What are the most pressing construction waste-related challenges faced by communities near Unki Mine, and how do these impact the community's daily life?
4. Are there any community-led efforts to reuse or recycle construction waste?
5. How does Unki Mine involve local communities in construction waste management decisions, and what improvements could be made?
6. What opportunities do you see for repurposing construction waste to benefit the community?
7. Could formalized waste recycling create jobs or income-generating activities for locals? What skills or resources would be needed?
8. What methods are most effective for educating communities about sustainable waste practices?
9. How are you and women currently participating in waste management, and how could their engagement be strengthened?
10. How can improved construction waste management contribute to the community's long-term social, economic, and environmental resilience?
11. You are free to share any other insights

Appendix 4: Interview guide for Environmental Management Official

Introduction

- Welcome participants and explain the purpose of the discussion.
- Emphasize confidentiality, voluntary participation, and respect for all voices.
- Briefly introduce the concept of a circular economy (e.g., "reusing waste to create value").

Key Questions

1. How do current national and local environmental regulations (e.g., EMA Act, mining policies) address construction waste management, and where do gaps exist in promoting circular economy practices like reuse or recycling?
2. How has improper construction waste disposal affected local ecosystems, public health, or infrastructure in the Shurugwi area?
3. What challenges has your organization faced in ensuring Unki Mine's compliance with mine construction waste management standards?

4. What opportunities do you see for aligning circular economy principles with Zimbabwe's environmental laws to reduce construction waste and enhance sustainability?
5. How can your organization strengthen partnerships with local governments, mines, and communities to pilot circular economy initiatives while balancing economic and ecological priorities?
6. Please feel free to share any other relevant information related to construction waste management in relation to Unki Mine's host communities.

Appendix 5: Interview guide for Tongogara Rural District Council Official

Introduction

- Welcome participants and explain the purpose of the discussion.
- Emphasize confidentiality, voluntary participation, and respect for all voices.
- Briefly introduce the concept of a circular economy (e.g., "reusing waste to create value").

Key Questions

1. What local by-laws or policies does Tongogara RDC currently enforce to regulate construction waste management, and how do they align with national frameworks like the Environmental Management Act or international standards?
2. How does the council monitor compliance with waste management policies? Are there mechanisms for auditing illegal dumping or incentivizing proper disposal, such as landfill taxes or subsidies for recycling?
3. What are the primary challenges Tongogara RDC faces in managing construction waste from Unki Mine's operations, particularly regarding waste segregation, recycling infrastructure, and community participation?
4. How does Tongogara RDC collaborate with Unki Platinum Mine to address waste management challenges? Are there joint initiatives to achieve the mine's 2030 zero-waste-to-landfill goal
5. Has the council explored circular economy strategies, Construction Waste Management Framework (CWMF), to repurpose waste into resources? What barriers exist in adopting such models?
6. What policy gaps or infrastructure investments does the council prioritize to enhance community resilience through circular construction waste management? Are there plans to formalize informal waste pickers or expand recycling facilities?

Appendix 6: Interview guide for District Development Coordinator's Office Official

Introduction

- Welcome participants and explain the purpose of the discussion.
- Emphasize confidentiality, voluntary participation, and respect for all voices.

- Briefly introduce the concept of a circular economy (e.g., "reusing waste to create value").

Key Questions

1. How is mine construction waste currently being managed within Unki Mine's host communities?
2. What are the benefits brought to you by the construction waste that is produced by Unki Mine?
3. What are the biggest environmental or health challenges your community faces due to construction waste from the mine?
4. How does Unki Mine engage with local people on construction waste management issues? Are these efforts effective?
5. As a district coordinator, how do you involve the community in decisions about waste management and mining activities?
6. What challenges currently hinder effective partnerships between the mine and stakeholders in addressing construction mine waste issues?
7. Are there local innovations locally that could help to repurpose construction mine waste that benefit the environment, people, and the climate?
8. What is your role in ensuring host communities actively participate in and benefit from circular economy initiatives?
9. Have waste-related disputes arisen between the mine and the community? How were they resolved?

Appendix 7: Focus Group Discussion Guide for Community Engagement Forum Members/ Villagers

Introduction

- Welcome participants and explain the purpose of the discussion.
- Emphasize confidentiality, voluntary participation, and respect for all voices.
- Briefly introduce the concept of a circular economy (e.g., "reusing waste to create value").

Key Questions

1. What types of construction or mining-related waste do you commonly see in your community?
2. How does construction waste affect your environment, health, or livelihoods?
3. Are there any local ways people reuse or dispose of construction waste (e.g., rubble, scrap metal)?
4. Would you support recycling waste (e.g., turning rubble into bricks) for community projects? Why/why not?
5. Could recycling construction waste create jobs or income for villagers? What ideas do you have?
6. What are the biggest barriers to managing construction waste here (e.g., lack of tools, knowledge, policies)?

7. How can villagers work together to reduce or repurpose construction waste?
8. What help (training, resources, etc.) would you need from the mine, government, or NGOs?
9. In your view, how can better waste management make this community stronger against future challenges?

Appendix 8: Observation checklist for field survey

Key Observation Areas

1. Waste Generation & Disposal Practices
   - Identify common types of construction waste (e.g., concrete, metals, and plastics) and their disposal methods (dumping, burning, and reuse).
2. Informal Recycling & Reuse
   - Document informal waste pickers, artisans, or households repurposing materials (e.g., using rubble for foundations, metal scraps for crafts).
3. Environmental & Health Impacts
   - Signs of pollution (e.g., contaminated water, air pollution from burning waste) or health hazards (injuries, respiratory issues).
4. Community Awareness & Attitudes
   - Assess knowledge of circular economy concepts (recycling, upcycling) and willingness to participate in formal waste programs.
5. Gender & Livelihoods
   - Roles of women/youth in waste management (e.g., collecting scrap metal, crafting from waste).
6. Unki Mine's Role
   - Mine waste management practices (e.g., recycling facilities, CSR programs) and community perceptions of mine accountability.
7. Infrastructure & Service Gaps
   - Availability of waste collection services, recycling centers, or barriers (e.g., distance, cost).
8. Traditional Practices & Innovation
   - Indigenous knowledge (e.g., using natural materials for construction) or innovative local solutions.
9. Conflicts & Governance

Observe tensions over waste dumping sites, land use, or mine-community relations.

Authors' Declarations and Essential Ethical Compliances

Authors' Contributions (in accordance with ICMJE criteria for authorship)

Contribution	*Author 1*	*Author 2*	*Author 3*	*Author 4*	*Author 5*
Conceived and designed the research or analysis	Yes	Yes	Yes	Yes	Yes
Collected the data	No	Yes	No	No	No
Contributed to data analysis & interpretation	Yes	Yes	Yes	Yes	Yes
Wrote the article/paper	Yes	Yes	No	No	No
Critical revision of the article/paper	Yes	Yes	Yes	Yes	Yes
Editing of the article/paper	No	Yes	No	No	No
Supervision	Yes	No	Yes	Yes	Yes
Project Administration	No	Yes	No	No	No
Funding Acquisition	Yes	No	Yes	Yes	Yes
Overall Contribution Proportion (%)	20	20	20	20	20

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The author(s) solemnly declare(s) that this research has not involved any human subject (body or organs) for experimentation. It was not clinical research. The contexts of human population/participation were only indirectly covered through literature review. Therefore, an Ethical Clearance (from a Committee or Authority) or ethical obligation of Helsinki Declaration does not apply in cases of this study or written work.

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Research Involving Local Community Participants (Non-Indigenous) or Children
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